

Incorporating supplier's learning in buying bundles

Merijn M. Linthorst
PhD candidate
University of Twente
PO Box 217, 7500 AE Enschede, The Netherlands
m.m.linthorst@utwente.nl
Telephone: +31 534894083
Fax: +31 534892159
(Corresponding author)

Jan Telgen
NEVI Professor of Purchasing Management
University of Twente
PO Box 217, 7500 AE Enschede, The Netherlands
Telephone: +31 534894532
Fax: +31 534892159
j.telgen@utwente.nl

Fredo Schotanus
Assistant Professor
University of Twente
PO Box 217, 7500 AE Enschede, The Netherlands
Telephone: +31 534893912
Fax: +31 534892159
f.schotanus@utwente.nl

Abstract

We consider the situation in which a purchaser can either buy a large quantity at the same time or sequentially in a number of smaller lots. Buying in a number of smaller lots obviously increases transaction costs. But buying in smaller lots provides the opportunity to the supplier to learn by discovering the true costs of supplying every lot. This is especially interesting for purchasers (and suppliers) operating in markets where little is known about the true costs of supply or where small margins require very accurate estimates. Using optimal learning modeling we analyze the effect of incorporating learning possibilities for suppliers into the bundling decision of the purchasing manager. We show that incorporating learning into bundles can have a significant effect on the total cost of acquisition. These results show purchasing managers the importance of an underestimated effect in bundling decisions: the learning effect.

Keywords: purchasing decisions, bundling, learning, contract forms

Educator & practitioner summary: This paper addresses the incorporation of learning in bundling decisions of purchasers. We show how the purchaser can minimize the total cost of acquisition by taking into account the learning effect that occurs with suppliers. Also we show under which parameters of the market this learning of suppliers is most effective.

Introduction

In the search for more efficient buying and better deals purchasing managers have to choose between buying services and goods in large bundles or in several small lots. The tendency is to choose for large bundles to profit from effects like quantity discounts and lower transaction costs. However, large lot sizes lead to an increase of risk and uncertainty for suppliers, at least for some types of bundling. This can cancel out the expected positive effects. This increase can lead to high failure costs or unexpected high bids, especially in contracts where items, to be delivered sequentially in time, are bundled (Lonsdale, 2008). In these contracts the risk and uncertainty about the future, are forced upon the suppliers. For example for a number of sequential jobs in road repairs in one bundled contract, a lack of experience or knowledge about the actual costs per job will lead to a multiplication of the risk involved by the number of jobs in the bundle. In a single job contract such multiplication is not necessary. Information about previous single job contracts might lead the supplier to incorporate a lower risk factor in his bid for the bundled contract.

Using information to optimize the judgement of future events is known in academic literature as optimal learning (Frazier et al., 2008). In these cases we have to make decisions under uncertainty, but we assume we know the probability distributions of the uncertain variables, like in the case of road repairs: how much variations will there be in the sorts of road repairs? Optimal learning then looks at how observations of the real world can help to improve assumptions. Optimal learning is applied in many fields. For example, optimal learning is applied in auctions to estimate the optimal number of items to auction based on earlier auctions results (Pinker et al., 2000; Karuga et al. 2005). Another example is the classical problem of Cayley (1954), where optimal learning is used to determine the optimal number of candidates for a secretary position based on the already interviewed candidates. Although many applications of optimal learning have been reported on, no applications yet have been found in the purchasing literature on bundling decisions.

In this paper, we analytically study the impact of providing information about the jobs in previous short contracts to suppliers on the total purchasing costs. We stress that we analyze from the buyer's point of view: the learning by the supplier is used by the buyer to optimize his costs. A number of questions arise which we address in our analysis:

- When should a purchaser buy jobs in bundled or short contracts with respect to the supplier's learning effect?
- What is the effect if supplier's learning is incorporated by the purchaser?

By answering these questions the paper provides valuable guidelines for when and how to use the possibilities of learning in bundling decisions. In the following section, we describe a bundling decision from practice, within which we address the posed questions.

A bundling decision: road repairs

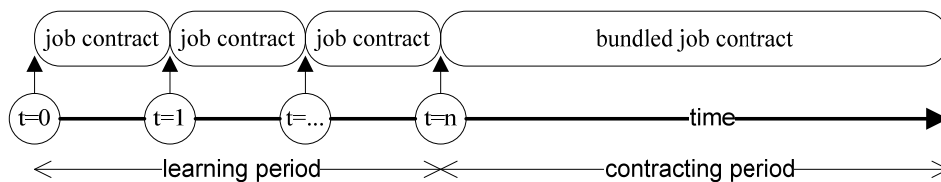
In this paper we consider the situation in which a purchaser has to buy a number of jobs in road repairs for a municipality. The road repairs jobs are typically small and require man hours and some material costs. They come up sequentially over time as a result of , heavy rainfall, sewage problems, tree root growth, cable digging, etc. Whenever the next job comes up, there is no uncertainty about its true costs.

Future jobs however do have the same characteristics, but are always somewhat different from the others due to specific situational circumstances. It is the actual composition of these future jobs that creates uncertainty.

Also the highly competitive markets for these works make the margins small and leave little room for the suppliers to make mistakes in their bids. This makes suppliers extra alert on risk and uncertainty.

In this situation the purchaser has to choose between buying a number of consecutive jobs in separate contracts or in one bundled contract (see Figure 1). At any moment t , the purchaser can decide to close a single job contract or a long-term contract that bundles the remaining jobs. We assume that executing the single job contracts provides information about the real costs of the jobs. When this information is passed on to the suppliers for sequential jobs, they will be able to place better bids through the better information available. But those single job contracts come at the cost of higher transaction costs. The purchaser should choose the length of the learning period in such a way that the additional transaction costs of the short job contracts are justified by better bids from the suppliers.

Figure 1: Sequential short job contracts to obtain information for the bundled contract



When asking for a bid for a short job or bundled contract, the purchaser can choose what information he should provide to the suppliers. To illustrate practical relevance thirteen purchasing managers of different Dutch municipalities were asked, what kind of information they feel they should provide under what kind of contract when asking suppliers for a RFQ for road repairs. In Table 1 we see that the purchasing managers showed very different approaches. Not only did they differ in approach of the contract (single jobs or bundled), they also varied in the information they provided the suppliers to learn.

Contract form	Information provided to the suppliers to learn	Information shortage for the supplier
1. Short term job contracts without learning	None	None
2. Bundled contract without learning	None	Future job costs and future deviations between jobs
3. Bundled contract with learning	Average historic job costs and deviation	None

Table 1: Contract forms, provided information and information basis for bids

We use these different contract forms in our analysis. In this way we can illustrate our research questions within a real world setting.

This paper is of an analytical nature. For the analysis of the problem of buying bundled contracts in road repairs we use the approach of optimal learning (Frazier et al., 2008). Optimal learning occurs primarily in applications where observations or measurements are expensive, for example expensive simulations or field tests. This fits with our problem of

buying road repairs, where the learning costs are the costs for a short job contract. We approach the problem of choice between long or short-term contract as a stopping problem in the optimal learning field. In this situation the suppliers have the opportunity to update their bids through updates in information about prior job costs. The costs of the previous job contracts are the observations used in these updates. We will analyze the effect of various learning strategies of suppliers on the bundle decision, using analytical techniques.

Literature review

Purchasers have considered bundling options for centuries, though little academic discussions seem to have been devoted to the bundling decision problem (Schoenherr and Mabert, 2008). Most of the bundling literature has been written from a seller's perspective in either the marketing or economics literature. Topics covered in this perspective are for example: the consumer evaluation of bundles (Soman and Gourville, 2001) or bundling as an entry deterrence mechanism (Nalebuff, 2004). The little research that is available from a purchaser's perspective considers the bundling decision in a reverse auction setting (e.g., Jap 2002, Schoenherr, 2008). More recent work has focussed on the various attributes of bundles and their effect on the bundling decision (Linthorst and Telgen, 2008; Linthorst et al., 2008). Some of these attributes of bundles and their effects are well known in practice, like for example the knowledge that a bundle with a large volume (attribute) generates more quantity discounts (effect). However, as mentioned by Linthorst and Telgen (2008), there are bundle attributes and effects that are less known in purchasing practice. One of those is for example the bundle attribute of subcontracting and its so called 'splitting effect' first analysed by Linthorst et al. (2008). They showed that if the supplier selects subcontractors inefficiently, the purchaser can realise substantial savings by buying from each subcontractor directly, instead of one large bundle.

The effects of bundling are a combination of all attributes as given by Linthorst and Telgen, 2008. In order to analyse each bundle effect separately, other effects need to be kept constant. For example, effects like quantity discounts (Schotanus and Telgen, 2009) is ignored in the analysis. To do so we have to formulate a key assumption for our analysis:

Assumption A1: Every other effect of bundling, except the effect of learning, is constant and therefore of no influence on the bundling decision.

When closing a contract for a bundled long-term or a short-term contract an important aspect is the contractual situation. Knight (1921) used a distinction between contractual situations under certainty and risk. A buyer or supplier with a contractual situation under certainty knows, *a priori*, accurately its requirements and costs. This is the case with the short job contracts in Table 1, when the road repair job is clear to the supplier; he knows what to provide, at what cost, extra information is not needed. If the contractual situation contains risk, the supplier knows the structure of the variables that can play a role in the delivery or buying of the bundle, but cannot, *a priori*, say how these variables are going to work out in the contractual period. Lonsdale (2005) mentions the example of a buyer who can foresee that his relationship with a supplier is likely to be affected by price variations based on the supplier's production inputs. However, it is not likely that it will be able to foresee the exact nature of those variations. It is this kind of risk that the supplier faces when generating a bid for a bundled contract. In these contract forms the supplier has to, in more or lesser extent, estimate the costs of jobs in the future, and incorporate risk in their bids (Lonsdale, 2005). In the light of this we argue that the suppliers of road repairs act in the same way as described by Lonsdale. Therefore we formulate two more key assumptions for our analysis:

Assumption A2: Suppliers cannot a priori accurately foresee the costs and the variation in costs of the road repair jobs over the length of a bundled contract.

Assumption A3: When increasing the risk by taking a bundled contract, the supplier will increase the compensation for risk in his bid.

In the next section we describe the model for the bundling decision of road repair under learning conditions.

The model

A supplier is asked to place bids for the road repairs contracts as described in the previous sections. For the sake of simplicity we assume one supplier for now. The sequence of events is as follows. The purchaser decides at time t to offer a short contract for the next job or a bundled contract for all remaining jobs that year (see again Figure 1). When a short contract is chosen, the supplier will bid for the job on the basis of costs-plus, charging exactly the real costs C_t plus margin m of the job. The transaction costs we assume as a . The costs of a short job contract can then be formulated as:

$$CC_{short}(t) = C_t + a + m \quad (1)$$

When a bundled contract is chosen, the supplier will estimate the mean $E(C)$ of the distribution of job costs for all road repairs. But because of the risk involved of making such an estimation (see assumption A2), the supplier will add a risk premium R to the mean C for each job in a bundled contract. In this way he is ensured of profit even when his prior estimation of the distribution of jobs appeared to be a poor one. However, with the delivery of each short contract prior to time t , the supplier can obtain information about the distribution of jobs. We see each short contract as an observation of the distribution. With each observation, the supplier can be more certain about his estimations, and therefore the risk will diminish (see assumption A3). We assume that the risk premium is given by $R/t - 1$; it is easily seen that this is downward sloping indicating the diminishing effect of learning on risk. The costs of a long bundled contract with length N can then be formulated as:

$$CC_{long}(t) = N \left(E(C) + \frac{R}{t-1} + m \right) + a \quad (2)$$

The purchaser is not only interested in the best bids for the road repair, but in the whole total cost of acquisition (TCS). When buying N number of sequential road repair jobs we can formulate the formula for TCS, for $n > 0$ as:

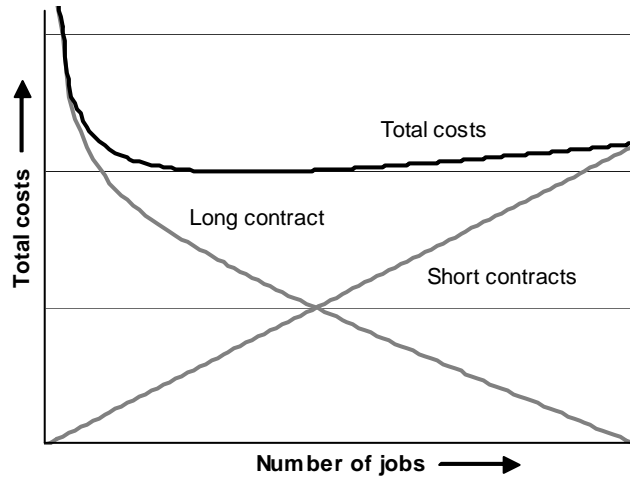
$$TCS(n) = \sum_{t=0}^{t=n-1} (C_t + a + m) + (N - n) \left(E(C) + \frac{R}{n} + m \right) + a \quad (3)$$

In this formula we are looking for the best time n^* , to stop with closing short job contracts and close a long bundled contract for the remainder of the jobs. The rationale is that by learning from the short contracts, the risk premium is reduced to such an extent that a long term contract becomes more suitable. Assuming that executing the road repair under real costs, will

in the long run, always lead to the real average costs C of the various jobs, for $n \succ 0$, we can rewrite (3) as:

$$TCS(n) = n \cdot (C + a + m) + (N - n) \left(E(C) + \frac{R}{n} + m \right) + a \quad (4)$$

Figure 2: Short, and long contract and total costs visualized



A visualisation of $CC_{\text{short}}(n)$, $CC_{\text{long}}(n)$ and $TCS(n)$ can be seen in Figure 2. In the next section we analyse how this formula can be used to calculate the optimal number of short contracts and find situations when to close only short contracts.

Optimal learning

The purchaser is expected not to get the cheapest bids for the road repairs, but to optimize the whole total cost of acquisition (TCS). In this view the goal is to get the best combination (minimal TCS) of short contracts and a long bundled contract.

We can show that there is an optimal time n^* that leads to the optimal total costs of supply. To do so we need to show that TCS is a convex function. Let us depart from the formula (4), which expresses the total cost of supply for the purchaser.. The first two derivatives of the $TCS(n)$ function are

$$\frac{dTCS(n)}{dn} = a - \frac{N \cdot R}{n^2} \quad (5)$$

and

$$\frac{d^2TCS(n)}{d^2n} = 2 \cdot \frac{N \cdot R}{n^3} \quad (6)$$

A first observation is that the second derivative (5) is positive for all $n \succ 0$ implying that $TCS(n)$ is a convex function. Secondly we see that filling in an n close to 0 in the first derivative, will have a large negative outcome. Filling in an n with a large number in the first derivative, will have an outcome approaching (a positive) a . This implies that an n^* exists and minimizing the TCS is therefore equivalent to setting the first derivative equal to zero.

In the same line of reasoning we can also pose that there is a certain value for the variables a , N and R , for which it is not worthwhile to close any short term contract, and just go along with a long bundled contract right away. This then resembles the contract form 2 in Table 1, the form of a bundled contract without learning. We can reason, looking at (4), that when the combination of total number of jobs and the risk are so insignificant compared to the acquisition costs a , a becomes dominant, and should be avoided at any cost. So closing a long bundled contract right away would be appropriate. In the following proposition we establish the value of a , for which it becomes dominant.

Proposition 1. For the proposed model, if the acquisition costs are larger then the risk premium ($a > N \cdot R$), a long bundled contract should be closed from the beginning.

Proof. When TCS is minimal for $0 < n < 1$, the decision to close a long bundled contract should be made before the first observation of a short job contract. It is then optimal to close a long bundled contract from the beginning. When the first derivative of TCS(n) is positive at $n=1$, we can assume that $0 < n^* < 1$. So by filling $n=1$ for the first derivative (5), setting $dTCS(1)/dn > 0$ and rewriting for a , gives $a > N \cdot R$. \square

Now look at the situation where the first derivative is negative at $0 < n < 1$. Using formula (5) we can formulate a pure strategy for finding the optimal n^* for this case. In the following proposition we establish the value for n^* .

Proposition 2. For the proposed model there is an optimal time, $n^* = \sqrt{N \cdot R / a}$ when to close a long bundled contract.

Proof. For $a > N \cdot R$ and $n > 0$ we can set the first derivative (5) equal to zero to find the optimal n^* . Rewriting $a - N \cdot R / n^2 = 0$ for n gives us the equations for the optimal time $n^* = \sqrt{N \cdot R / a}$. \square

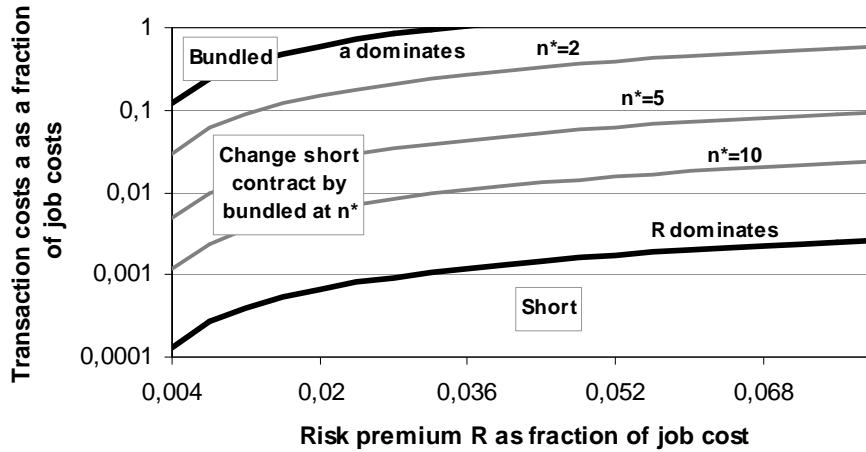
In another line of reasoning we can think of a situation that risk R is so high that even in the length N of the jobs, not enough can be gained from learning to reduce R . In this situation n^* approaches N and even surpasses it. Then it is best to close only short job contracts, which are risk free and accept the higher acquisition costs $N \cdot a$. This resembles the contract form 1 in Table 1. In this case it no longer pays to close any long bundled contract. In the following proposition we establish the value of R , for which it becomes dominant.

Proposition 3. For the proposed model, if the risk premium is larger than or equal to the acquisition costs $R \geq N \cdot a$, only short job contracts should be closed.

Proof. We can depart from the formula $n^* = \sqrt{N \cdot R / a}$ for the optimal n^* . If $n^* \geq N$, the learning period would be of such a length that it surpasses the planning horizon of the purchasing manager. In this case, it is more suitable to close only short job contracts. We can show this when we rewrite $n^* = \sqrt{N \cdot R / a}$ to the risk premium, $R = a \cdot n^{2,*} / N$. If we increase n^* such that it equals N , the formula becomes $R = N \cdot a$. Increasing n^* even further will further increase R . Therefore we can see that when R is bigger than or equal to $N \cdot a$, when $n^* \geq N$. So, $R \geq N \cdot a$. \square

With this analysis we have shown that, given the assumptions of the model, there exists an optimal time n^* when to close a bundled contract after learning from short contracts (Propositions 1 and 3). Whether this n^* falls within the decision horizon $1 \leq n \leq N$, depends on the relation between the risk premium, number of jobs N and acquisition costs (Propositions 1 and 3). If we have a fixed N , we can visualize the values of R and a , for the optimal contract forms to be used in Figure 3.

Figure 3: Optimal contract forms for various acquisition costs and risk premiums



We can link these situations to the real strategies we discussed in beginning of this paper. In Table 2, we show the same three types of contracts forms with the same difference in information provision and learning as in Table 1. As we have analyzed, we can now link every type of contract form to an optimal situation, with or without learning.

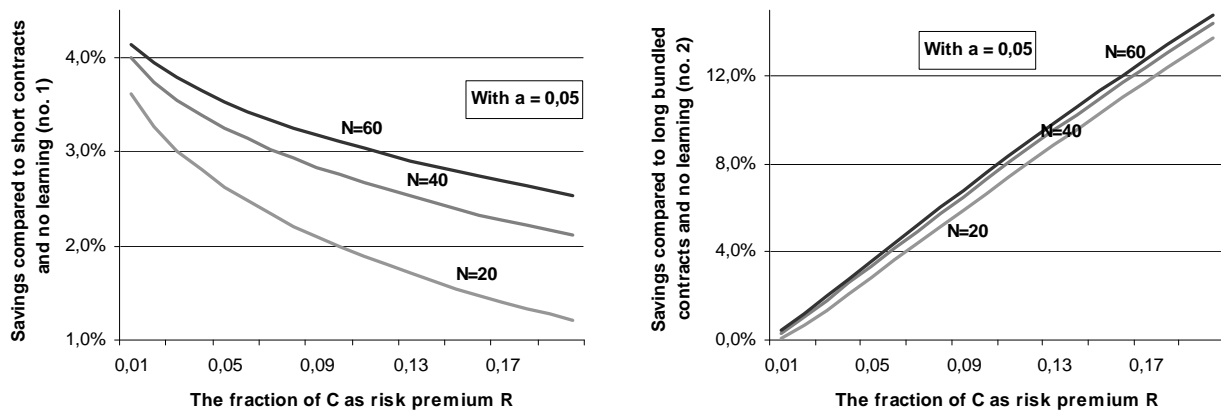
Situation	Proposition	Contract form
Risk dominates: $R \geq N \cdot a$	3	1. Job contracts without learning No information provided to the suppliers
Acquisition costs dominate: $a > N \cdot R$	1	2. Bundled contract without learning No information provided to the suppliers
No domination: $N \cdot R > a > R/N$	2	3. A bundled contract with n number of job contracts preceding to let the supplier learn with the formula: $n^* = \sqrt{N \cdot R / a}$

Table 2: The situations in which each contract form, with learning possibilities is optimal, given the model

Analysis of the learning effect

In the previous section we have shown when purchasers should follow a learning strategy when buying small road repairs. In this section, we show the effect of learning itself. Suppose the use of learning is optimal, as it is in contract form 3, what is the effect when we use no learning as in form 1 and 2? We will simulate this learning effect by varying the parameters involved. To add reality to the outcomes, we assume that both risk and acquisitions costs a are related to the average costs of the jobs C , with fractions α and β , making $R = \alpha * C$ and $a = \beta * C$. In Figure 4 the learning effect is displayed as the percentage savings when using the optimal contract form instead of short contract (contract form 1) or long contracts (contract form 2) without learning. We vary the risk premium R as fraction of average job cost C , and keep transaction cost constant.

Figure 4: the learning effect for various values of R and N while a is constant



In Figure 4 we can see that with an increasing risk premium the savings decline, in comparison with short contracts. Apparently the learning effect is not so high when risks tend to be high and the suboptimal contract form 1 (only short contracts) is chosen. However, when the suboptimal contract form 2 (long, bundled contract without learning) is chosen, high risks can lead to significant differences with the optimal strategy. Therefore extra caution should be taken when choosing contract form 2 in a situation with high risk for the suppliers. In Figure 5 we display the learning effect as a function of transaction costs a as a fraction of average job cost C , and keep the risk premium constant.

Figure 5: the learning effect for various values of a and N while R is constant

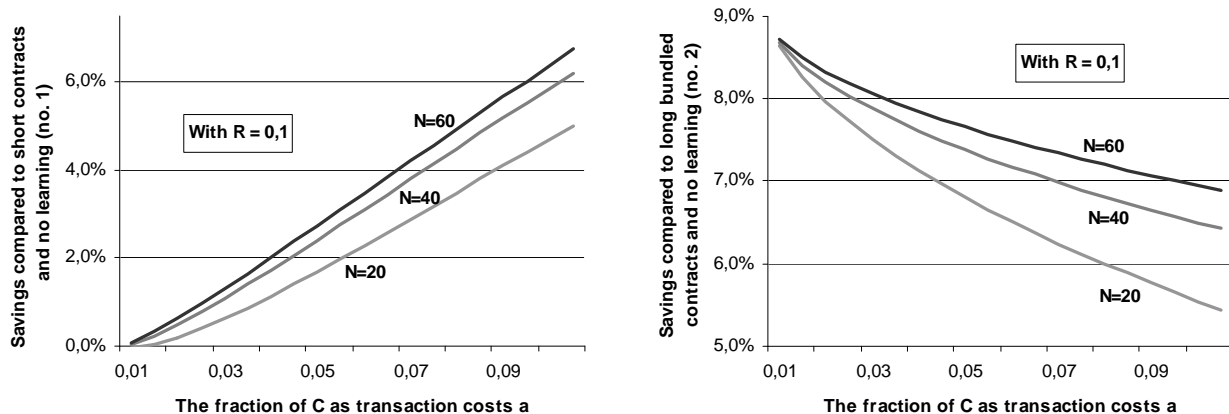


Figure 5 shows that when transaction cost tend to be low, the difference of suboptimal contract form 1 (short contracts), and the optimal contract form, is minimal. However, this climbs rapidly, with increasing transaction costs. Also, in a situation with low transaction costs, choosing for the suboptimal contract form 2 (long contract without learning), can lead to an increase of the total acquisition costs of over 8 percent. Therefore extra caution should be taken when choosing contract form 2 in a situation with low transaction costs.

Conclusion

This research has both managerial and theoretical implications. From a managerial standpoint we show by analytical means that there is an optimal way of incorporating learning in the purchaser's bundling decision. Especially for situations of buying a large number of sequential jobs, such as road repairs, we formulate the optimal situation when to use learning. Furthermore, we show that if learning is not used in this situation, this can lead to significant higher total costs for the purchaser. The bottom line is that purchasing managers have to be aware of the learning effect when making the bundling decision. Extra attention should be paid in situations when short contracts are chosen when risks are low and transaction costs high, or when a long bundled contract is chosen when risks are high and transaction costs low. It is in these cases that the learning effect is highest. From a theoretical standpoint we show that optimal learning can contribute to decision making in purchasing. Modeling these situations proves to create general propositions that can be used to further build theory in bundling decision making. Although the model itself is simple, it creates a foundation for further understanding of the use of optimal learning in purchasing situations.

This research is limited by the assumptions made for the model. In a real setting the bundling decision is made based on many effects of bundling. In this paper we only analyze one of those effects. It is the purchaser's role to combine the insights of this paper with the judgments on other bundling effects. Also the model is now based on the learning curve R/n that diminishes with more observations n . Many other learning curves can be considered, including updating the learning curve using Bayesian statistics. Clearly there are several interesting aspects of this problem that create research opportunities.

References

- Cayley, A., 1954. Mathematical questions with their solutions, no. 4528. Educational Times, 23:18, pp. 1875.
- Jap, S.D., 2002. Online reverse auctions: issues, themes, and prospects for the future. Journal of the Academy of Marketing Science, 30:4, pp. 506-525.
- Karuga, G., S. Nair and A. K. Tripathi, 2005. Sizing of lots in identical-item sequential online auctions. Working paper, University of Connecticut.
- Knight, F., 1921. Risks Uncertainty and profit. New York: Harper and Row.
- Linthorst, M.M. and J. Telgen, 2008. The splitting value, analyzing the value of buying in separate lots. Working paper, Proceedings of the 17th IPSERA conference, Perth, pp. 461-468.

Linthorst M.M., J. Telgen and F. Schotanus, 2008. Buying bundles: the effects of bundling attributes on the value of bundling. Working paper, Proceedings of the 15th Euroma conference, Groningen.

Lonsdale, L., 2008. Contractual uncertainty, power and public contracting. *Journal of Public Policy*, 25:2, pp. 219-240.

Nalebuff, B., 2004. Bundling as a entry barrier. *Quarterly Journal of Economics*, 119:1, pp. 159-187.

Pinker, E., A. Seidmann and Y. Vakrat, 2000. Using transaction data for the design of sequential, multi-unit, online auctions. Working paper CIS-00-3, Simon School, University of Rochester.

Frazier, P., W. B. Powel, and S. Dayanik, 2008. A knowledge gradient policy for sequential information collection. *SIAM Journal on Control and Optimization*, forthcoming.

Schoenherr, T., and V.A. Mabert, 2008. The use of bundling in B2B online reverse auctions. *Journal of Operations Management*, 26, pp. 81-95.

Schotanus F, J. Telgen and L. de Boer, 2009. Unraveling quantity discounts. *Omega*, 37:3, pp. 510-521.

Soman, D. and J.T. Gourville, 2001. Transaction decoupling: How price bundling affects the decision to consume. *Journal of Marketing Research*, 39 (February), pp. 30-44.